



Connecting everything you see to the internet could revolutionise the way we live. Mike Bedford looks at how scientists are seeking ways to put the whole world online

Everything, from the chair you're sitting on to the tree outside your window, could one day be a part of the internet. That might sound daft, but the United Nations is taking it seriously. Two years ago, the UN commissioned a report from the International Telecommunication Union (ITU), the UN agency responsible for regulating communications worldwide. The report was called *The Internet of Things*, and it looked at the next step in always-on communications. In short, it examined how a communications network might include real-world objects and places as well as data, which is mostly what the internet is restricted to today.

According to the lead author of the ITU report, Lara Srivastava, "The Internet of Things implies a future in which the number of users of the internet will grow exponentially. Not only will humans, PCs and mobile phones have the potential to access the network of networks, but so too will everyday items, from toothbrushes to tyres, from textbooks to boots."

For Srivastava the early signs of an Internet of Things are already visible today in the retail world as more and more consumer goods are tagged for inventory management, and in the healthcare sector, as medical equipment and pharmaceuticals are more easily tracked. But Srivastava is cautious. "A full-fledged Internet of Things, in which the majority of real objects

could be mapped in the virtual world, will most likely take some 20 years."

Two decades is a long time. However, it has been two years since the ITU report was published so we should be seeing the emergence of some of the mechanisms that the Internet of Things will require, if it is ever to come into existence.

OBJECT LESSONS

Putting objects on the internet is not new. Ever since researchers in the computer laboratory at Cambridge University trained a camera on their coffee pot to view it remotely in 1991, academics have revelled in giving all sorts of objects a home on the web. Robots, model railways and interactive art installations are just a few of the objects you can view and control via the web.

There's a serious side to this, too. State-of-the-art home-automation systems allow you to control central heating, lighting and much more via the web or a mobile phone. All these devices contain processors, but the Internet of Things aims to encompass these and dumb objects, too. Increasingly you will be able to interrogate such mundane objects as posters or even lamp-posts.

But how could a lamp-post possibly be networked and, more pertinently, why would anyone ever want to do so? Tom Hall, travel editor for the Lonely Planet guidebooks, says



▲ Lonely Planet's Yellow Arrows allow travellers to recommend places of interest to others

that it's not so much the lamp-post that is of interest, but where it is situated. The Lonely Planet book *The Guide to Experimental Travel* suggests unusual ways of enjoying the travel experience. Of particular interest is the section on Yellow Arrow (www.yellowarrow.net). When it was first published, the book came with a few



◀ Contributors to the Grafedia project write a tag that looks like a hyperlink on physical objects. Other users then contact this address to retrieve an image

sample Yellow Arrows for readers to use to recommend places, views and experiences to other travellers. "Find something that is interesting, perhaps a café or a view, and stick an arrow on anything you can find nearby, for example a lamp-post."

Each arrow has a unique code printed on it. When someone puts up a Yellow Arrow they register it by texting a message from their mobile phone, or sending text plus a photograph or a map via the web. Once this has been done, anyone stumbling across the Yellow Arrow just texts or emails its code to receive information associated with it. Yellow Arrows have also been used to create interactive city guides. There's no more rummaging around in your backpack to find that dog-eared copy of your travel guide or city map; you just text the code on each arrow to learn about your current location and receive directions to the next place on the itinerary.

Similar in concept is the Grafedia project (www.grafedia.net). Unlike Yellow Arrow, it

doesn't cost you a penny to tag a place, but there's a downside from an environmental viewpoint. To put a location online you have to write an email address, such as myfavouriteplace@grafedia.net, on a nearby object. This address also has to be in blue and underlined so that it looks like a hyperlink. Judging from the photographs on the Grafedia website, most people do this using blue spray paint, a marker pen or chalk.

Where Yellow Arrow is mainly for sharing text, with photographs as a secondary consideration, Grafedia is first and foremost about images. To tag a place, you send a photograph from your mobile phone to the Grafedia email address you've chosen. Others will retrieve your image by sending a blank email to that same address. Grafedia is not a commercial website, so whether or not it works depends on whether or not the people running it are keeping up to date with site maintenance. It looks as if the site hasn't been active this year,

which could indicate that this is a bit of a dead end in the evolution of the Internet of Things.

Yellow Arrow claims that arrows are posted in 395 cities in 37 countries and that 1,581 people have registered. But this is just a drop in the ocean compared to the number of potential users with internet access. The project has a cult following, mainly in the USA and Scandinavia, and has been particularly successful in connection with certain events. At an arts festival in New York, for example, 10 Yellow Arrows posted by festival organisers attracted thousands of hits in a single week.

If these sorts of markers were a truly useful or interesting way of linking the internet to the outside world, the web would be awash with imitators. But it isn't. Neither Yellow Arrow nor Grafedia have enjoyed mass-market appeal. That isn't really surprising given that accessing either requires a considerable amount of user input. Both show the potential for the Internet of Things, but they're not the way this new internet will work in the future.

RFID TAGS

Radio Frequency Identification (RFID) tags have received a good deal of media coverage recently, thanks to their use in everything from ID cards to getting your rubbish bins to spy on you. RFID tags, which are starting to appear on the goods we buy, can be read from a distance of a few metres and the reader doesn't have to be in the line of sight of the tag.

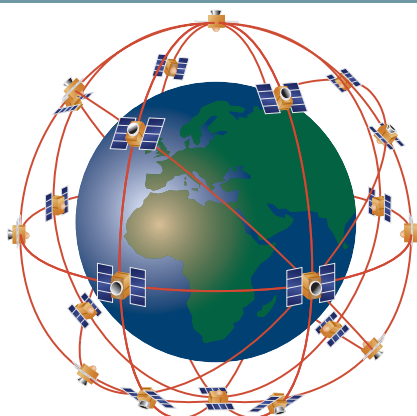
This could mean shorter queues at supermarket checkouts, as instead of each object having to be scanned individually, a whole trolley full of groceries could be scanned almost instantaneously. But there's another major difference between RFID tags and the barcodes they are replacing. Whereas a barcode represents a number just a few digits long – enough to identify that the object is, for example, a 250g jar of Marmite – RFID tags have

How it works Assisted GPS

GPS works by timing signals transmitted by navigational satellites. Each satellite sends pulses at precisely known times so, by recording the time the signals are received on Earth, a handheld GPS receiver or in-car satellite navigation device can work out how far it is from some of the 24 satellites in orbit. Most of the satellites aren't visible from any particular location, but a GPS receiver needs to be able to get signals from at least four to get a fix. Knowing how far it is from one satellite is enough to place the receiver somewhere on the perimeter of a sphere centred on that satellite.

Similar information from a second satellite places the receiver on the perimeter of a second sphere, which means the actual location is one of the points where these two spheres intersect. This intersection, however, is a circle in space, so timing information from a third satellite is required to provide another sphere. The intersection between this and the circle is just two points.

Because one of these points is likely to be way out in space or, perhaps, in the middle of the Earth, these three satellites might seem enough to provide a location. The snag is



▲ The NAVSTAR GPS system uses 24 satellites orbiting the Earth in six paths. To get a position, the user receives signals from four satellites

that all this requires very accurate timing. The satellites have precise but very expensive atomic clocks onboard, but in-car sat-navs and mobile phones do not. What's more, because radio signals travel so quickly, even a timing inaccuracy of a few millionths of a second would put the location way out. Fortunately, a distance from a fourth satellite provides a

solution. By using four satellites the timing error is cancelled out, allowing a position to be calculated to an accuracy of just a few metres.

This system applies to ordinary GPS, but many of the newer 3G mobile phones offer Assisted GPS (AGPS). Here, rather than having to perform all the work in the handset, the job of tracking satellites and working out a location is shared between the mobile phone and the network base stations.

One of the main areas in which the base stations provide assistance is in finding satellites. When a GPS receiver is first switched on, it can take a few minutes to search, build up a list of all the satellites that are visible from that location and download their orbital data. This is annoying to the user and it wastes valuable battery life. In an AGPS system, the network keeps track of the satellites and, whenever a handset needs to work out its location, it will provide it with information about the ones that ought to be visible.

Some implementations of AGPS also offer clever techniques to allow it to work indoors, which can be tricky with ordinary GPS.



a number long enough to represent every single item ever manufactured.

Since RFID tags are sometimes fixed to the item itself, not just its packaging, it is understandable that privacy campaigners are concerned about this use of the technology. For example, say you present a loyalty card when paying for RFID-tagged clothing. The store would be able to identify you the next time you returned wearing the item, should it have the inclination and technology installed to do so.

To date, RFID tags have been mostly of benefit only to manufacturers and retailers, with few apparent advantages to consumers. However, this is a technology that experts believe may soon fuel the Internet of Things, and it isn't hard to see why. Concepts such as Yellow Arrow and Grafedia are likely to be nothing more than stepping stones on the way to the Internet of Things because of the user action required to access them. But accessing information associated with an RFID tag would be no more complicated than pressing a button.

GRAPHICAL TAGS

Initially, benefits to the consumer are most likely to be via specialised equipment such as RFID-enabled washing machines and microwave ovens. We won't be able to use RFID to interact with objects and places as we now do with webpages (at least not in the near future) because most PCs and mobile phones aren't equipped with built-in RFID readers.

However, most mobile phones have a camera. One obvious method for tagging places or objects so that they can be interrogated automatically using handheld devices is some sort of graphical marking that can be read digitally. The humble barcode is such a graphical mark and it would be quite possible, using specific software, to scan barcodes using a mobile phone's camera. Although ordinary barcodes are capable of representing only short strings of digits, newer types of barcodes can represent much longer alphanumeric strings.

One advanced barcode that is popular in Japan is called the Quick Response (QR) code. You can read how it works on page 133. The Active Print project (www.activeprint.org) is a group of companies that aims to explore how printed materials and digital displays can be linked to online content, services and applications using a mobile phone. If the aspirations of Active Print come to fruition, we can expect these square QR barcodes to start popping up here in the UK on anything and everything from concert posters to bus stops and tourist information plaques.

What happens when someone points their camera phone at something tagged with a QR code? Active Print partner HP is developing an application called Glass, which runs on a camera phone. "The data we encode is rather like that in a hyperlink in a webpage: there's a Uniform Resource Identifier (URI) and some text that links to it. The URI could be a web URL, a telephone number to dial, a text message, or just some data, as in a business card. Whichever type of URI is involved, Glass makes the phone respond to it as though the user had just typed it in," explained Tim Kindberg, senior researcher at HP's Bristol laboratory.

"So the phone requests a webpage, dials a number, sends an SMS and so forth. And the text in the code pops up and scrolls across the

Chill factor What happened to the internet fridge?

For years now we've been hearing about internet fridges, and in fact a few models came to the market about five years ago. But despite all the hype about what internet fridges might be able to do, the first models were little more than a fridge with a flat-panel, touch-sensitive screen fitted to the door and an internet-enabled PC hidden away somewhere inside. To say that they didn't take the world by storm would be an understatement. After all, why would you choose to browse the web standing in front of your fridge when you could do so sitting at a desk or in an armchair in the lounge?

But the internet fridge is far from dead, according to Samsung's Chae Hee-kook. In a statement made just a few months ago, Samsung revealed it was working on a new intelligent fridge that would do a lot more than display webpages on its door. Using RFID technology, the fridge would keep track of groceries as you put them on its shelves or removed them. If milk or orange juice were to run low, for example, the fridge would notify its owner. Alternatively, it could offer recipes using the available ingredients.

You wouldn't have to be standing next to the fridge to interact with it. You could call the fridge from the supermarket to check what groceries were over their expiry date and what you needed to buy. Eventually, the fridge will be able to re-order goods



▲ The internet fridge will be available "some time soon", apparently

automatically for delivery directly from the supermarket. When will you be able to pick up one of these RFID fridges from your local electrical store? Chae Hee-kook told the *Korea Times*: "Some foretell 2008 or 2009 as the debut year of our RFID fridges. But we can't say for sure because nobody knows when RFID tags will become widespread."

phone's screen when you read the code, before there has been any network access. We find that users really like that responsiveness."

But the need to have special software in the phone to interrogate QR codes would seem to limit the take-up of this technology. A way of doing this without requiring additional software would be for the user to transmit an image of the code via a picture message so it could be interpreted remotely. HP explored both possibilities. "We have found through extensive user trials that real-time responsiveness is vital to the user experience," said Kindberg. "With Glass, the user points the camera at the code running at video rate and moves the phone slightly until they see the pop-up text appear. With a mechanism involving taking a picture, the user first takes a still image of the code, secondly sends it to a service, thirdly waits an indeterminate amount of time until the answer comes back, and finally is almost certainly told 'could not decode' because the image was blurred, or not all the code was in the picture. [You're] back to step one and frustration."

PHYSICAL EDUCATION

The QR code seems to be just one contender for hyperlinking real-world objects. Could Yellow Arrow, Grafedia, RFID, QR codes and other barcode variants coexist in the future or would one become the standard method? According to Kindberg "We at HP Labs have been pioneers in what we called the 'Real-world wide web', long before the term 'Internet of Things' became popular. We experimented with various technologies to create what we called physical hyperlinks: infrared beacons, RFID tags, barcodes, iButtons and so on. Any mechanism involving significant input into a handset and

hence user effort is good only for niche applications. So that eliminates Yellow Arrow and Grafedia tags from having a future."

Kindberg feels there is a future for both RFID and barcodes. "They involve little user effort. Mobile phone readers are available in both cases, so there can be billions of readers in users' hands. The costs of the tags themselves are low, so we can have the necessary trillions of tags. Barcodes have great advantages over RFID. They cost almost zero, just a little ink. And they can be read by existing camera phones, so there's no new hardware. RFID tags will always cost more than barcodes. And new hardware is needed on the handset. But RFID tags can in principle be read more robustly because there's no dependency on reasonable lighting conditions, and they can be made robust against environmental rigours – my dog has one in his neck."

HOPE AND GLORY

A couple of projects completed by the Active Print project give a glimpse into the future. In 2005, the Bristol-based record company Hope Recordings used Active Print technology to promote a compilation album *Seven Year Itch*. QR codes appeared on posters for the album as well as in adverts in magazines. By pointing their phones at the posters or advertisements, fans could download videos and music clips to get a taste of the album.

At the same time, the popular BBC *Coast* series used similar technology to guide viewers on a series of coastal walks. At each point along the walks there was a BBC *Coast* sign containing a Data Matrix code (a 2D barcode that is similar to the QR code) and instructions on how to use it. On arriving at a sign, hikers pointed their



mobile phone's camera at the Data Matrix code and, within seconds, multimedia content appeared on the screen explaining the significance of the current location and giving directions to the next stop on the route.

GEOGRAPHICAL TAGGING

All the methods we've seen so far for tagging real-world objects are suitable for things that can move around. If something is rooted to the spot, however, there's an alternative way of giving it a place on the internet. Buildings, mountains, rivers and the like can be identified purely from their geographical location and there are a number of ways of accessing that information automatically.

For super-accurate positioning there's satellite-based GPS, which forms the basis of navigation systems. GPS adaptors are available for notebooks and PDAs and even some 3G mobile phones now have built-in GPS circuitry that can give a position, accurate to a few metres, anywhere in the world.

For a somewhat less accurate position, any mobile phone can work out its approximate location from knowledge of the base station (mast) it's connected to and how strong the signal is from that base station. Mobile phone companies and third parties are already exploiting this capability by providing location-based services. With the advent of assisted GPS (see page 130) providing an easier and faster

way to use GPS, this could be an important step towards the Internet of Things.

At the moment, the most common use of location-based services is to allow people to find businesses in an area they are unfamiliar with. The 'where's my nearest?' service that's offered by many of the network operators lets you ask for the name, address and telephone number of the nearest hotel, Chinese restaurant or petrol station, for example. In London, the Zingo taxi-hailing service puts you in contact with the driver of the closest black cab. Location-based games such as Geocaching, which is essentially a high-tech treasure hunt, have also gained a cult following.

The world's first location-based multimedia tour, History Unwired, was jointly developed in 2005 by MIT and the University of Architecture in Venice. The location-based technology used for the tour was a combination of assisted GPS – a 3G technology that uses the mobile phone network to improve the performance of GPS in urban areas with poor satellite coverage – and Bluetooth. Bluetooth was used to trigger a couple of interactive artworks that had been installed along the walking route when a signal from a Bluetooth-enabled mobile phone was detected.

Taking the form of an interpreted walking tour around Venice's Castello neighbourhood, visitors were guided by the voices of locals who related anecdotes or gave their insight into art

and craft, history and folklore. Some just talked about their own lives to paint a human picture of Castello. For instance, a Venetian boat builder explained how he got started in his profession, and a glassblower demonstrated his craft in his studio. The tour contained a mix of audio, video, maps and animation and ran to 50MB.

THE FACE OF TOMORROW

The World Wide Web is around 15 years old, and the Internet of Things is in its infancy. So will the Internet of Things be influencing the world of tomorrow as its predecessor does today? On the face of it, the evidence is not compelling. After all, the ITU's report was published two years ago and, although a few pilot studies were completed in 2005, nothing much seems to have happened since in the UK.

However, if we look to Japan we see an entirely different picture. Here, QR code has become ubiquitous over the past two years. The codes appear in business cards, magazine adverts, on posters and even on the packaging of a Big Mac. So why is there such a great divide? The big difference is that in Japan nearly all mobile phones are shipped with software for reading QR codes already installed, whereas in Europe you'd have to download it from the web and install it on your phone. As long as this state of affairs continues, the Internet of Things will be nothing more than a plaything for the technically minded here in the UK. **ES**

How it works QR code

QR code is the up-and-coming technology for tagging real-world objects. An ordinary barcode is one-dimensional, which means it is scanned in a single direction. This was necessary for the scanning hardware that was available in the 1970s and 1980s when barcodes were first rolled out, but it severely limits the amount of data a single barcode can hold. With today's low-cost digital-imaging devices and the processing power available in handheld devices, this restriction need no longer apply.

The latest generation of barcodes is two-dimensional, and one of the most popular is the QR code. It can hold 7,089 characters of numeric data or 4,296 alphanumeric characters, which is almost a page of this article.

The code shown below represents the Shopper URL, www.computershopper.co.uk.



▲ QR code depicting the Computer Shopper URL, www.computershopper.co.uk

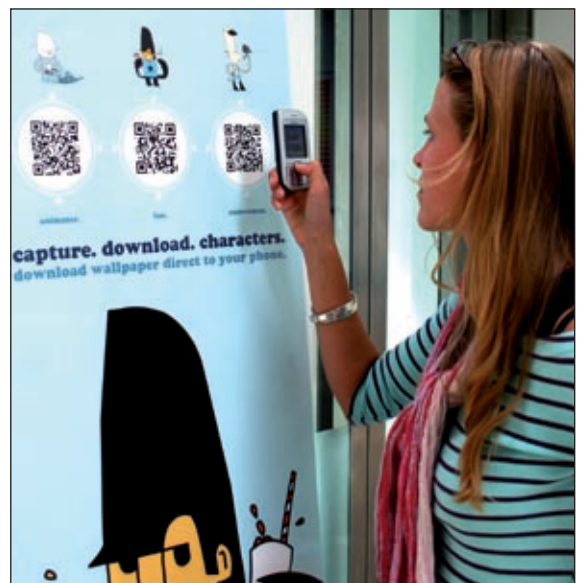
Immediately noticeable are the square targets in three of the four corners. These are position-detection patterns and are used by the reader to determine the orientation of the code. This way the code can be scanned from any angle.

QR codes are defined according to their symbol version and their error-correction level, the combination of which dictates their data capacity. The symbol version defines the number of black and white squares, which can vary from 21x21 to 177x177. The one shown here is a version 3 code, which means it is arranged as a 29x29 block array and it can store up to a 127-digit number or a 77-character text string.

The squares represent the zeros and ones of binary data.

But the encoding of numeric data and text isn't just a simple matter of turning the zeros to white squares and the ones to black squares, because of the error-correction feature. This feature allows the codes to be read even if a corner is torn off or a mark conceals some of the pattern.

There are four error-correction levels – L, M, Q and H – each one representing a trade-off between the resilience to damage and data capacity. Level H, the most secure, permits the data to be fully read even if 30 per cent of the code is damaged.



▲ QR codes contain far more data than conventional barcodes. They are now a common sight in Japan

The error correction uses a mathematical function called a Reed-Solomon code. The mathematics is complicated, but suffice to say that, before being put into the QR code, a mathematical operation is carried out on the data. The result is a longer data stream, and the length increases with the amount of security provided by the chosen error-correction level. However, because the additional error-correction information is spread throughout the data, it is possible to restore the original data, irrespective of where the damage occurred.